Retention of students to science, technology, engineering, and mathematics (STEM) major has been studied for four cohorts participating in a summer bridge program supported by the National Science Foundation. Students participated in a 6-week program prior to their first term of enrollment at a research-intensive land grant university. Comparisons to baseline incoming classes from 2009–2011 show gains in retention to major out to the third year for underrepresented minorities (African American, Hispanic, Native American), first-generation college students, and females. Gains for underrepresented minorities and females are statistically significant, whereas those for first-generation students are not. These gains are associated with participation in a 6-week summer bridge program and the resulting improvement in preparation for college coursework, sense of belonging as measured by qualitative surveys, and use of academic support structures. Qualitative data support the theory that students need social integration and a sense of belonging in addition to academic support structures to persist in STEM. We conclude that bridge programs should address the “whole student” and not simply academic coursework.

Science, technology, engineering, and math (STEM) education is both a lynchpin to success and an area requiring improvement in the United States. It is crucial to the country’s continued economic recovery and to the continued status of the United States as a leader in the interplay between science, technology, and society (National Science Board, 2010; “Not What it Used to Be,” 2012; Obama, 2009, 2013; Snyder & Dillow, 2013). Simultaneously, undergraduate science education in the United States is considered to be underperforming in the recruitment, preparation, and graduation of a cohort of diverse scientists and engineers large enough to drive the U.S. STEM enterprise (“Not What it Used to Be,” 2012; Obama, 2013). It is also an unfortunate reality that “the proportion of underrepresented minorities in S&E would need to triple to match their share of the overall U.S. population” (National Academy of Sciences, 2011, p. 3). What can we do to recruit and then retain a diverse population of STEM students while also maximizing their growth during their undergraduate career so they are prepared to contribute to society? This article will describe Ohio’s Science and Engineering Talent Expansion Program (OSTEP), a precollege summer bridge program for STEM students, and present results associated with its success regarding the affective learning (i.e., social integration and sense of belonging) and academic support of the participants.

At The Ohio State University (OSU), OSTEP is modeled on an existing summer bridge program offered by the Minority Engineering Program called PREFACE (Pre-Freshman and Cooperative Education Program). A full description of the program with lessons learned can be found in Tomasko et al., 2013. Although PREFACE focuses on underrepresented minorities in engineering disciplines, OSTEP focuses on first-generation students and underrepresented minorities in all STEM disciplines. When referring to these programs in this article, we will use OSTEP as an umbrella term to describe the activities and participants in both programs.

Tinto (2010) identified expectations, support, feedback, and involvement as conditions necessary for student success. He described the importance of the faculty and institution clearly communicating expectations for students and of students having clear expectations of what they need to do to succeed. He also discussed the importance of having academic and social support systems in place so that student growth from their individual starting point is
nurtured. When students are learning in a supportive environment, they can develop self-efficacy that leads to future success. Feedback helps students have a better understanding of how well they are performing compared with expectations, which makes them more aware of their own learning and the strategies that help them learn. Involvement, or engagement, increases student ties to academic and social structures. OSTEP supports all of these conditions by helping the pre-freshman students clarify their expectations of university life, develop academic and social structures in classes and dormitory living, receive feedback regarding their performance in noncredit-bearing classes, and get involved with a group of students with whom they will interact during their years at OSU. In this study, we investigate student sense of preparedness, which includes student clarity of academic expectations (based somewhat on feedback) and use and awareness of academic supports. We also investigate student sense of belonging, which is influenced by their expectations of campus culture, the OSTEP social support network, and their involvement in OSTEP-related activities.

Students frequently leave their STEM major because they are not well prepared to learn the concepts (Gleason et al., 2010) and do not expect the pace and classroom environment found in many STEM classes. Additionally, they leave because they do not feel part of the STEM community or because they do not perceive the relevance of their studies (Hoyt & Winn, 2004; Tinto, 2010). Conversely, high-impact educational practices such as undergraduate research, study abroad, active learning, and internships correlate to improved persistence and graduation rates in STEM. Numerous studies have shown that most high-impact educational practices take place outside of the classroom (Kuh, 2008).

Research has indicated that sense of belonging is important to college students (Strayhorn, 2012). Strayhorn’s (2012) working definition of sense of belonging in terms of college is as follows:

students’ perceived social support on campus, a feeling or sensation of connectedness, the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the group (e.g., campus, community) or others on campus (e.g., faculty, peers). (p. 122)

It appears that sense of belonging is important for underrepresented groups, especially those majoring in STEM fields (Strayhorn, 2008, 2011). OSTEP offered students opportunities to increase their sense of belonging in the university STEM community.

Bridge programs are a common method to introduce students to the rigor of college coursework and the study skills necessary to succeed in their chosen major. Although there are many different types of precollege bridge programs, a common component is the preparation of students for what they will experience academically and socially in college (Kezar, 2000). Many are designed for students with conditional acceptances or in need of remediation and focus on preparing students to meet the challenges of college courses (Walpole et al., 2008). The National Science Foundation Science and Engineering Talent Expansion Program (STEP) provided support to increase the number of students obtaining STEM degrees at any level. Many STEP projects incorporate bridge programs as a method to improve the success and retention of students entering STEM majors.

Even though little research has been conducted to evaluate the impact of bridge programs (Garcia & Paz, 2009; Strayhorn, 2011), previous work has suggested that summer bridge programs can have a positive effect on academic skills and self-efficacy. Even though others have reported their investigations into the usefulness of bridge programs, few have used control groups (Kezar, 2000; Suzuki, Amrein-Beardsley, & Perry, 2012). Residential bridge programs provide an opportunity for students to develop along multiple dimensions (McCurrie, 2009). First, they experience realistic coursework without the pressure of a transcripted grade. This allows students to discover how well prepared they are and usually proves to them that they don’t know how to study well. Second, the common experience during a residential program builds a strong community among the participants that lasts well into their university careers. Others have reported that their summer bridge program appears to have had some impact on retention and recommended looking more deeply into impacts of the social aspects on retention (Tinto, 2010). We interpret these social aspects to be related to affective learning and a sense of belonging.

OSTEP targeted recruitment of underrepresented groups, in particular first-generation, minority, and Appalachian students in all STEM majors from the pool of admitted students. These groups have been targeted to enhance the diversity of
degree-seeking students in STEM and because they may need additional support to navigate university systems and succeed in their STEM major. Demographics of the participant cohorts are shown in Table 1 and illustrate that we were successful in attracting high percentages of our targeted populations to participate in the program. In the table, we show the combined demographic numbers and percentages of participants across our first four cohorts (2009–2012) compared to a baseline university population from the corresponding year when available (summer and autumn STEM admits for 2009–2011 were available). We observed that the percentages of each demographic do not vary greatly with time. Additional details of the structure of the program have been presented previously (Tomasko et al., 2013).

This article will address the following research questions associated with the OSTEP Bridge Program:

- Do students feel prepared for entry into a STEM major following participation in the OSTEP program?
- Do students feel a sense of belonging following participation in the OSTEP program?
- Does use of academic resources (math/stats learning center) improve performance?
- Is participation in the OSTEP program associated with improved retention in a STEM discipline?

**Methods**

We use descriptive statistics and qualitative data to illustrate how outcomes from our summer bridge program are associated with retention in a STEM major. Next we describe the surveys used to measure student preparation and sense of belonging, and student use of academic resources, as well as our definition of STEM major and how we determined retention.

**Preparedness and sense of belonging**

We administered surveys to each cohort at the beginning and end of the summer bridge program and are able to include data here for five cohorts (2009–2013). These surveys contained items specific to the bridge program. Additional surveys with different items were administered to participants and control groups once they were engaged in their college classes, but because these surveys addressed different questions and had low response rates, those responses will not be reported. Likert questions included as part of the former surveys queried participant attitudes and feelings regarding the impact of the summer bridge program with 14 items in response to the prompt “Please indicate the degree to which you agree or disagree with each of the following with respect to your experiences with this program.” The Likert scale, closed-response items on the survey were scored as follows: 5 = strongly agree, 4 = agree, 3 = no opinion, 2 = disagree, and 1 = strongly disagree. In addition, participants responded to the open-ended question, “What impact do you think this program had on you?” By considering both the closed- and open-response items, we add validity to our analyses.

To analyze the open-ended responses, we first developed a scoring guide that identified key terms for preparedness and each component of sense of belonging that would be identical or similar to the actual terms that the students used. We asked content experts (Tomasko and Strayhorn) to review the scoring rubrics to ensure the face validity of the preparedness and sense of belonging rubrics. The preparedness rubric identified comments associated with the program being helpful to participants in better preparing them for university life, including academic and nonacademic aspects. We considered students making

<table>
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<th>TABLE 1</th>
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<tbody>
<tr>
<td>Demographics of participants combined across all cohorts (2009–2012). The last two columns show our baseline university data represented by the students admitted to the university in the summer and autumn terms of 2009–2011 and intending to major in a STEM discipline.</td>
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<tr>
<td>--------------------------------------------------</td>
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<td>--------------------------------</td>
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<tr>
<td>URM</td>
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<tr>
<td>First generation</td>
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<tr>
<td>Female</td>
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<tr>
<td>Total</td>
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<tr>
<td><strong>Note:</strong> OSTEP = Ohio’s Science and Engineering Talent Expansion Program. URM = underrepresented minority.</td>
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</table>
gains in the understanding of course content as well as having clearer expectations of the workload, difficulty, and thought processes associated with their academic courses as aspects of preparedness. In addition, we considered comments associated with familiarity with the campus and dorm life as indications that students were better prepared for college life. The sense of belonging rubric scored comments based on Strayhorn’s (2012) definition.

Following a training exercise with 10 comments to ensure a shared understanding, the authors (Ridgway and Waller) scored all of the student responses to the open-ended question. Several times during scoring they discussed and made modifications to the scoring guide to clarify their process. When the scoring was complete, the scores for each response were compared, and a Cohen’s Kappa was calculated for feeling of preparedness and each component of sense of belonging for each cohort. The Kappas ranged from 0.6 to 1.0, which indicates that they achieve moderate to high interrater reliability. The raters looked at each disagreement together, and following the discussion achieved complete consensus on all responses, resulting in Kappas of 1 for each category within each cohort. Disagreements were due to oversights or minor differences in interpretation, which were clarified during the consensus process.

Academic resources

We collected grades of the participants in the first math course they took at the university (regardless of level) and identified the number of visits they made to the Mathematics and Statistics Learning Center or MSLC (http://mslc.osu.edu/), which is a drop-in center run by teaching assistants and student tutors from the Mathematics and Statistics Departments. We coded the frequency as 0 = 0 visits, 1 = 1 visit, 2 = 2–3 visits, and 3 = more than 3 visits and then compared the mean course grade between those who visited MSLC (codes 1–3) and those who did not (code 0) in four courses (Math 148: College Algebra; Math 150: Elementary Functions or Precalculus; Math 151: Calculus I; and Math 152: Calculus II). All procedures are included in approved IRB protocol 2008B0087.

Retention to STEM

At our university, students must declare a major within a particular college, and the college confers the degree. Therefore, enrollment records indicating college and major are used to identify STEM students. It is possible but generally unlikely that a student would be enrolled in a particular STEM major but not be pursuing the corresponding STEM degree. We define a student retained to a STEM major as one who is currently enrolled in the autumn term in a degree program or major in the Colleges of Engineering (ENG), Mathematics and Physical Sciences (MPS), or Biological Sciences (BIO). Since our project started, our university has restructured MPS and BIO into the Division of Natural and Mathematical Sciences (NMS) in the College of Arts and Sciences (ASC). Engineering remains as a standalone college. This definition of STEM major excludes majors and degree programs in the College of Food, Agriculture, and Environmental Sciences such as animal science, environmental science, food science and technology, entomology, and plant pathology. However, our participant data does not include students from these programs so their exclusion does not impact the results below.

We are interested in determining if OSTEP is associated with difference in retention of underrepresented groups, which included African Americans, Native Americans, Hispanics, and people from “two or more races.” The “two or more races” demographic category is relatively recent and is calculated two different ways in this study. For university data on retention of underrepresented minorities, all students from the “two or more races” demographic are included. In our analysis of the smaller number of participants, we only counted students as underrepresented minorities if one of the races they identified was African American, Native American, or Hispanic. We believe that this difference in counting students as underrepresented has minimal impact on the results because we have been informed by the registrar that an overwhelming majority of students identifying as “two or more races” selected African American as one of those racial groups.

For our participant cohorts (OSSTEP participants), we use the Student Information System to determine their current major after the enrollment census date (typically the 15th day of the term) each autumn. For comparison data, we obtain from the university registrar a “mobility table” describing the enrollment patterns for cohorts of entering “new first quarter freshmen” (NFQF). Some schools refer to this as new starts or first-time, full-time students. The mobility tables show the initial distribution of students among the different colleges (undecided students can still be enrolled
in the college of their choice with few exceptions and are generally counted as intended majors in that college). The cohorts are then tracked as they progress through the university, and each autumn, a new distribution of students among the different colleges is produced. In this work, we take the sum of NFQF enrollments in ENG, MPS, and BIO for AY 2009–2011 as the incoming STEM cohorts for comparison. Each autumn, the number of OSTEP participants is subtracted from the total STEM enrollment in the mobility tables, and the remainder determines STEM retention for the university at large. A chi-square analysis is used to determine whether OSTEP participant retention to a STEM major is statistically different from the university. Mobility tables show enrollment only and do not enumerate graduates of each college so it is not possible for us to determine cohort-based graduation rates from these tables. Conversations with the registrar are ongoing to obtain graduation-rate data.

Results

Preparedness

Responses to both the open- and closed-response items on the end-of-summer survey indicate that students feel better prepared for college. Figure 1 shows the closed-response items indicating that students ($N = 184$) feel better prepared to succeed at OSU (average score range 4.6–4.8), feel more comfortable with OSU (average score range 4.8–4.9), and have improved study skills (average score range 3.5–4.5).

In addition, in response to the question, “What impact do you think this program had on you?” students overwhelmingly responded with an indication of being better prepared (range among cohorts, 78%–96%). Error bars representing one standard deviation in the response variable are shown.

In the following typical comment, the student indicated increased academic preparedness: “It prepared me for my freshman math, chemistry, and physics courses and put me in a position to enter ahead of the curve and excel in the fall.” Other students mentioned changes in their study habits and clearer college expectations: “It helped build study skills that I needed to learn”; “I broke bad habits that I
had received from high school”; “It helped me realize, even more so, how serious college is and that from before day one I need to make sure that I have my goals set out and am ready to reach them.” Students mentioned that the clearer expectations decreased their anxiety and helped them know that they can succeed.

**Sense of belonging**

Responses to both open- and closed-response items also indicate that students gained a sense of belonging associated with their participation in OSTEP, but their response was not as overwhelming as it was to preparedness. The closed-response items shown in Figure 2 indicate that students (N = 211) made friends (social support on campus, average score range 4.6–4.8), were more comfortable with science faculty (feeling of connectedness, average score range 4.2–4.4), and were part of a study group that would continue in the academic year (part of a group, 3.1–4.1). Error bars representing one standard deviation in the response variable are shown to indicate the variation in response values.

When reviewing the open-ended results across cohorts, 5%–16% of the students indicated that they had increased their social support, usually with comments about the friends they made; 3%–10% indicated that they had an increased feeling of connectedness to a specific identity, such as OSTEP or OSU; and 2%–10% indicated that they were part of a group or community. One student indicated feelings of connectedness by saying, “Having become a buckeye, . . .” The most frequent indicator that students felt they were part of a group is the

**TABLE 2**

Participants’ mean GPA and DEW rate in first math class. Our university uses E instead of F as a failing grade.

<table>
<thead>
<tr>
<th></th>
<th>Math 148</th>
<th>Math 150</th>
<th>Math 151</th>
<th>Math 152</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Math GPA (4.0 scale)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No MSLC average</td>
<td>2.42</td>
<td>2.58</td>
<td>2.14</td>
<td>2.29</td>
</tr>
<tr>
<td>MSLC average</td>
<td>3.01</td>
<td>2.28</td>
<td>2.50</td>
<td>2.90</td>
</tr>
<tr>
<td><strong>DEW rate (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No MSLC</td>
<td>16.7%</td>
<td>20%</td>
<td>25%</td>
<td>21.1%</td>
</tr>
<tr>
<td>MSLC</td>
<td>0%</td>
<td>0%</td>
<td>25%</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Note: MSLC = Mathematics and Statistics Learning Center.*

**FIGURE 3**

Retention to STEM major results for Ohio’s Science and Engineering Talent Expansion Program (OSTEP) cohorts compared with all university STEM majors. Retention for Cohort 4 is statistically different than the university after the 1st and 2nd year (p < .10).
mention of becoming part of a study group.

**Academic resources**

As shown in Table 2, for three of the four math courses observed, OSTEP participants who used the MSLC had a higher average GPA than those who did not. In all math courses except Pre-Calculus (150), the average increase in course grade was at least 0.4, which would translate into a half-grade improvement. It is notable that the DEW rate for participants who used the MSLC was 0% for all courses except Calculus I (151), whereas the DEW rate for those who did not was at least 16.7%.

**Retention to STEM**

Student retention to STEM major is shown in Figures 3–6. As noted in the Methods section, graduation-rate data by cohort and major for the entire university is not readily available to us. Instead, we show retention to the 3rd year only because data for engineering students show that third-year retention is a strong indicator of the 6-year graduation rate (the latter is consistently 3%–4% lower than the former). Although this indicator may not hold true for all science majors, our STEM population consists of at least 50% engineering students, and we feel this is a valid measurement for comparison.

Participants in the bridge program are retained to STEM majors at or above levels exhibited by the university STEM population (Figure 3). Although the differences may appear small, it is important to note that the participants in this study are primarily drawn from demographics that are frequently considered to be at-risk of leaving STEM or the university. The program has shown consistent results across 4 years of offering and continues to demonstrate success in this metric (preliminary data for most recent cohorts not shown). Retention to a STEM major generally is much lower than retention to the university overall, which we believe is true at most research-intensive universities. Underrepresented minorities in STEM are compared in Figure 4. Our programs have a relatively high percentage of underrepresented minority students and show some statistically significant improvements in retention of this population after the 1st and 2nd years. Females are underrepresented in engineering but not necessarily in the biological sciences. We include them as a separate demographic group here for completeness. Figure 5 shows again a strong positive gain in persistence to the 3rd year for participants compared with all females entering as STEM majors. Some of the gains after the first 2 years are statistically significant. First generation participant retention is shown in Figure 6 and indicates positive gains in persistence over the university population out to the 3rd year for all but Cohort 1, but none are statistically significant.

**Discussion**

OSTEP has targeted underrepresented groups who have historically been poorly retained at colleges and universities, especially in STEM majors. Our data indicate that OSTEP
students are well-prepared and have a strong sense of belonging. In addition, those participants who took advantage of academic support services, such as the MSLC, perform better in their classes than others who do not take advantage of those services. Reducing the DEW rate in the mathematics courses translates into greater efficiency—students might not need to retake courses so tuition dollars and time are not wasted.

Our data also indicate that the OSTEP participants are retained in their STEM discipline better than the general population of students admitted to STEM majors at the university. However, our female, underrepresented minority, and first-generation participants show much stronger retention to STEM than those groups in the total university STEM population, especially for our latter cohorts (Cohort 1 shows the smallest improvement for all targeted groups). Cohorts 2 and later are on track to show an improvement in retention of over 10 percentage points for female students in STEM. The improvement is in the range of 8–10 percentage points for underrepresented minority participants and 5–10 percentage points for first-generation participants. Interestingly, the gains in retention for our targeted groups compared with their counterparts are greater than the gains for the total participant group compared with all STEM students. Still, our participants are retained as well as or better than the entire cohort, which is evidence for having “leveled the playing field” for retention of targeted populations. We interpret strong preparation, support, and sense of belonging nurtured in OSTEP to be associated with these improvements in retention.

Similar to the conclusions of Suzuki et al. (2012), we found that the STEM students were better prepared and had a greater sense of belonging at the university following their experience in a bridge program. We acknowledge that student responses might change regarding the value of their experiences in the bridge program after they are immersed in their collegiate lives, with challenging coursework and a less controlled life outside of class. Nonetheless, considering the data we collected and our definitions of preparedness and sense of belonging in relation to expectations, support, feedback, and involvement, our study supports Tinto’s (2010) assertion that these conditions are related to improved student retention.

**Conclusion**

We demonstrate that a summer STEM bridge program targeting populations underrepresented in STEM and first-generation college students can improve persistence to the 3rd year in a STEM major with measurable improvements over the general STEM population at a research-intensive university. Further, qualitative measures support the theory put forward by Tinto, Suzuki, and Strayhorn, among others, that students need social integration and a sense of belonging in addition to academic support structures to persist in STEM. We conclude that bridge programs should address the “whole student” and not simply aca-
demic coursework. Challenges to be addressed include finding scalable approaches that can be implemented to impact additional students.

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